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# Comparison of Broiler Litter and Commercial Fertilizer at Equivalent N Rates on Soil Properties

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*A 3-year study was conducted to determine the effects of broiler litter relative to inorganic fertilizer on soil nutrient content and quality in an upland Loring silt loam soil. Treatments included annual broiler litter rates of 0, 2.2, 4.5, 5.6, 6.7, 10.1, and 13.4 Mg ha<sup>-1</sup> y<sup>-1</sup> and commercial fertilizer rates of 34, 68, 90, 112, 134, and 168 kg nitrogen (N) ha<sup>-1</sup> y<sup>-1</sup>. Broiler litter application linearly increased soil total carbon (C), microbial biomass C, extractable soil phosphorus (P), potassium (K), soil cation exchange capacity (CEC), and the stability of soil aggregate. At the highest broiler litter rate, the stability of soil aggregate was 34% greater than inorganic fertilizer. Application of broiler litter or fertilizer N at rate greater than 6.7 Mg ha<sup>-1</sup> or 90 kg N ha<sup>-1</sup>, respectively, exceeded plant N utilization potential as evidenced by higher end-of-season soil residual nitrate (NO<sub>3</sub>)-N. Broiler litter is more effective in improving soil physical, chemical, and biological components than conventional fertilizer.*

**Keywords** Aggregate stability, biomass C, broiler litter, soil quality, upland soil

## Introduction

Fertilizing crops with inorganic nitrogen (N) sources is believed to benefit soil by increasing soil organic carbon (C) through boosting crop growth and plant residue (Dick 1992) followed by improving soil chemical, physical, and biological properties (Perrott, Sarathchandra, and Dow 1992; Fraser, Haynes and Williams 1994). Some recent studies, however, revealed that long-term N fertilization depletes soil organic carbon by promoting the decomposition of crop residues and soil organic matter leading to deterioration of soil quality (Khan et al., 2007). Barak et al. (1997) reported that long-term N fertilization decreases levels of exchangeable calcium (Ca), magnesium (Mg), potassium (K), and soil cation exchange capacity (CEC). Regardless of the negative effects of long-term N fertilization on soil quality, N has been applied intensively in row crop productions.

As commercial fertilizer N prices rise, interest in using broiler litter N as an economical alternative to commercial fertilizer for row crop production has been considered.

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Application of litter to cotton (*Gossypium hirsutum* L.) as an N source has been shown to be an agronomically viable alternative (Reddy, Nyakatawa, and Reeves 2004; Sistani et al. 2004; Tewolde, Sistani, and Rowe 2005; Tewolde et al. 2007). However, in most of the studies, manure was compared with fertilizer as a single recommended rate or fertilizer combined with manure as supplement (Liu et al., 2001; Tewolde et al. 2007). Determining the effects of chemical fertilizer and manure at equivalent N rate will improve manure management and strengthen crop advisers' confidence in broiler litter nutrient credits, which can lead to minimizing offsite nutrient movement.

Some studies have indicated manure applications improved soil quality compared to chemical fertilizer (Edmeades 2003; Adeli et al. 2007) because manure supplies an additional exogenous source of organic matter, which influences the capacity of soil to store and release nutrients for crop growth during decomposition and mineralization (Lal 2002). Others have shown a decline in soil quality or fertility (Sharpley et al. 1998; A. Kumar and Yadav 2001; Zhang et al. 2002). For example, Sharpley et al. (1998) indicated that long-term application of broiler litter can negatively influence soil productivity and quality by creating potential nutrient imbalance in soil fertility. However, Lu et al. (2001) indicated that fertilization with inorganic N did not have a significant effect on changes in soil quality. These conflicting reports from both manure and commercial fertilizer justify the necessity for research on the effects of different rates of manure relative to chemical fertilizer at equivalent available N rate on soil productivity and quality.

In a long-term manure application study on grassland, Christie (1987) reported that manure and fertilizer had similar effects on crop production. In row crops, Mitchell and Tu (2005) compared three different rates of broiler with commercial fertilizer at equivalent plant available N for cotton in a silty clay loam and a sandy loam soil and concluded that total N in litter was as effective as N from ammonium nitrate for cotton yield. However, the effects of these nutrient management practices on soil quality were not reported. The comparability of broiler litter with fertilizer at equivalent N rate to cotton on soil quality is lacking in the literature. Most of the work on long-term effects of animal manure on soil productivity and quality has been done on grassland and pasture in Europe and the northern United States (Borghi et al. 1995; Berzsenyi, Gyoreffy, and Lap 2000; Bronick and Lal 2005; Karlen et al. 2006). With recent interest in using broiler litter for row crops in Mississippi, the relative impact of broiler litter and fertilizer on soil nutrient dynamics and properties in the southeastern United States, particularly in Mississippi agro-ecosystems, is lacking in the literature and is not documented. The objective of this study was to determine the effects of broiler litter relative to inorganic fertilizer at equivalent N rates applied on soil chemical, physical, and biological properties in an upland soil.

## Materials and Methods

This study was conducted at the Mississippi Agricultural and Forestry Experiment Station of Mississippi State University, North Branch near Holly Spring, Mississippi, on a Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs) soil from 2002 to 2004. Initial soil samples were taken from the 0–15 cm depth. Initial soil chemical characteristics are shown in Table 1. The experimental design was randomized complete block with 13 treatments replicated four times. A plot consisted of eight rows spaced 0.97 m apart and 15.2 m long. Treatments included broiler litter application of 0, 2.2, 4.5, 5.6, 6.7, 10.1, and 13.4 Mg ha<sup>-1</sup> y<sup>-1</sup> applied at total N rates shown in Table 2. Inorganic fertilizer was applied at the rate of 34, 68, 90, 112, 135, and 168 kg N ha<sup>-1</sup> y<sup>-1</sup>. The source of commercial fertilizer N was NH<sub>4</sub>NO<sub>3</sub>. The field was disked and bedded up each year. In the spring, before

**Table 1**  
Initial chemical characteristic of the soil at the 0–15 cm depth

Parameter	Value
pH	4.92
Total C (g kg <sup>-1</sup> )	10.59
Total N (g kg <sup>-1</sup> )	1.14
NH <sub>4</sub> -N (mg kg <sup>-1</sup> )	19.0
NO <sub>3</sub> -N (mg kg <sup>-1</sup> )	7.04
M3P (mg kg <sup>-1</sup> )	68.9
WSP (mg kg <sup>-1</sup> )	4.2
K (g kg <sup>-1</sup> )	0.23
Cu (mg kg <sup>-1</sup> )	1.09
Zn (mg kg <sup>-1</sup> )	1.82
Bulk density (g cm <sup>-3</sup> )	1.36

planting cotton, a commercial fertilizer was broadcast and incorporated over the entire inorganic fertilizer N plots at the rate of 39 kg P ha<sup>-1</sup> and 112 kg K ha<sup>-1</sup> in 2002 and 34 kg P ha<sup>-1</sup> and 65 kg K ha<sup>-1</sup> in 2004. The sources of phosphorus (P) and K fertilizers were triple superphosphate and potassium chloride (KCl), respectively. Before planting cotton, broiler litter and commercial fertilizer N were applied by hand and incorporated into the soil within 2 days of application. Broiler litter was obtained from a commercial broiler producer in northern Mississippi every year and kept under cover at the research site before application. Broiler litter samples were collected at the time of application for nutrient analyses. Total N and total C contents in broiler litter were determined using an automated dry combustion C/N analyzer (model NA 1500 NC; Carlo Erba, Milan, Italy). Total P and other element such as K, Ca, Mg, copper (Cu), and zinc (Zn) contents of broiler litter was determined by dry-ashing a 1-g sample according to procedures outlined by Issac and Kerber (1977) and measured using inductively coupled argon plasma spectrophotometry (ICP; Thermo Jarrel Ash; Iris Advantage ICP, 40669, Houghton, Michigan). Chemical analysis of broiler litter and the amount of nutrient applied each year are shown in Tables 2 and 3.

Each year after picking cotton, the cotton stalks were shredded and soil samples from the center of each plot were taken to 90 cm depth and divided into 0- to 15-, 15- to 30-, 30- to 60-, and 60- to 90-cm increments. Four cores (2.5 cm in diameter) were taken, composited for each plot and depth in the field, mixed thoroughly, and a representative subsample was taken for analysis. Soils taken from 0–15 cm depth were divided into two different bags. One bag was stored at 5 °C until being analyzed for water content and biological properties. The remaining soil plus the samples taken from other depths were air-dried, ground to pass through a 2-mm sieve, and stored at room temperature until analysis.

Measured soil chemical and biological properties included soil pH, total C, total N, Mehlich III extractable P, exchangeable Ca, Mg, and K, cation exchange capacity (CEC), and microbial biomass C. Soil pH and electrical conductivity were determined using 0.01 M calcium chloride (CaCl<sub>2</sub>) on a 1:1 w/w basis and pH was determined using a glass electrode (pH/electrical conductivity (EC)/total dissolved solids (TDS); meter model 19813-0, Hanna, Woonsocket, Rhode Island). Total C and total N in the soil were determined for 0–15 cm depth from air-dried, finely ground soil using an automated dry combustion C/N analyzer (model NA 1500 NC). Soil samples were extracted with 2 M KCl and

**Table 2**  
Yearly total nutrient rates supplied by broiler litter applied to the soil in each year

Treatment	2002					2003					2004				
	N	P	K	Cu	Zn	N	P	K	Cu	Zn	N	P	K	Cu	Zn
$\text{Mg ha}^{-1}$ ( $\text{kg ha}^{-1}$ )															
2.2	60	31	46	0.82	0.76	62	34	61	1.09	0.92	52	25	43	0.71	0.40
4.5	123	70	104	1.85	1.71	126	69	126	2.22	1.89	107	51	87	1.44	0.83
5.6	153	87	130	2.29	2.12	157	86	156	2.77	2.25	133	64	106	2.28	1.03
6.7	184	105	155	2.75	2.55	188	103	187	3.32	2.81	159	76	130	2.15	1.23
10.1	277	158	234	4.14	3.83	284	155	282	4.99	4.23	240	115	196	3.24	1.86
13.4	367	209	311	5.49	5.01	377	205	374	6.63	5.61	319	154	260	4.30	2.46

**Table 3**  
Chemical analysis of broiler litter used in the study

	2002	2003	2004	Average
pH	7.03	7.2	6.9	7.04
Total C (g kg <sup>-1</sup> )	270	331	335	312
Total N (g kg <sup>-1</sup> )	27.4	28.1	23.8	26.4
Total P (g kg <sup>-1</sup> )	15.6	15.3	11.4	15.1
K (g kg <sup>-1</sup> )	23.2	27.9	19.4	23.5
Ca (g kg <sup>-1</sup> )	25.3	26.2	18.7	23.4
Mg (g kg <sup>-1</sup> )	5.3	5.6	3.9	4.9
Cu (mg kg <sup>-1</sup> )	409	495	321	408
Zn (mg kg <sup>-1</sup> )	378	419	184	327

inorganic N (ammonium (NH<sub>4</sub>)-N + nitrate (NO<sub>3</sub>)-N) in the extract were measured using a Lachat instrument (QC 800 flow injection analyzer; Lachat, Loveland, Colorado). Soil P in Mehlich III extracts was measured using ICP. Soil microbial biomass C (MBC) were determined using the microwave irradiation method (Islam and Weil 1998). Exchangeable Ca, Mg, Na, K, Cu, and Zn were determined by displacement with 1 M ammonium acetate at pH = 7 and subsequently measured by ICP. Cation Exchange Capacity was determined by summation of exchangeable base cations (Ca<sup>+2</sup>, Mg<sup>+2</sup>, K<sup>+1</sup>, and Na<sup>+1</sup>) (Warncke and Brown 1998). Soil bulk density and stability of soil aggregate was determined in soil samples taken at the beginning (2002) as initial soil samples and at the end of growing season of the third year. Soil bulk density was determined using a procedure described by Grossman and Reinsch (2002). A typical double-cylinder, hammer-driven core sampler was used for obtaining soil samples for bulk density. A 15-cm ring was placed inside the sampler, inserted by force into the top 0–15 cm depth, and the whole core was taken. Samples were trimmed from the top and bottom of the ring, weighed, and oven-dried at 105 °C. The volume of the soil was calculated based on the dimension of the ring. Soil bulk density was calculated by dividing the mass of soil by the volume. Soil aggregate stability was determined on 2-mm sieved air-dried soil by a modified turbidimetric method (Williams et al. 1966).

The general linear model (GLM) procedure in SAS (SAS Institute 1996) was used to perform an analysis of variance (ANOVA). Data were analyzed using a simple regression model, which included linear and quadratic trends. ANOVA using single degree of freedom comparisons was performed to contrast fertilizer against broiler litter for all measured variables. All differences mentioned in the discussion are significant at  $P \leq 0.05$  unless stated otherwise.

## Results and Discussion

### Soil pH

Averaged across years, surface soil pH slightly decreased with increasing inorganic fertilizer N rates (Table 4). Broiler litter application had the opposite effect with increasing litter rate increasing soil pH. At the highest rate (13.4 Mg ha<sup>-1</sup>) broiler litter increased soil pH by 0.45 compared to the control (Table 4). Hue (1992) reported that broiler litter contains

(Continued)

Variable	df	pH	BD (g cm <sup>-3</sup> )	TC	TN (g kg <sup>-1</sup> )	MBC	M3P (mg kg <sup>-1</sup> )	M3K	AS <sup>†</sup> (%)	CEC (cmol <sub>+</sub> kg <sup>-1</sup> )
Year										
2002		5.05	1.34	10.3	1.18	367	102	247	19.4	20.5
2003		5.01	1.32	11.1	1.23	380	118	314	25.5	24.8
2004		4.91	1.29	12.7	1.35	391	128	387	22.2	26.5
Treatment										
Litter										
	Fertilizer (kg N ha <sup>-1</sup> )									
0	0	4.96	1.35	10.1	0.96	282	80	250	20.4	17.5
2.2	0	5.13	1.33	10.7	1.16	376	103	282	21.8	20.1
4.5	0	5.17	1.33	11.5	1.24	401	114	320	22.5	21.2
5.6	0	5.18	1.32	11.6	1.29	415	126	328	22.9	22.0
6.7	0	5.21	1.31	11.8	1.31	446	141	368	28.2	24.7
10.1	0	5.35	1.28	13.2	1.46	459	147	400	29.2	27.6
13.5	0	5.41	1.26	14.2	1.59	496	166	456	31.6	31.3
0	34	4.90	1.36	10.4	1.11	330	90	252	22.1	18.4
0	67	4.85	1.35	10.7	1.14	333	104	265	21.9	18.1
0	90	4.83	1.36	10.9	1.16	330	104	260	20.5	19.3
0	112	4.82	1.37	11.2	1.20	336	108	266	21.6	20.0
0	135	4.77	1.36	9.4	1.22	321	105	270	20.2	19.7
0	168	4.76	1.37	9.6	1.33	305	100	268	20.8	20.1

Table 4  
(Continued)

Variable	df	pH	BD	TC	TN	MBC	M3P	M3K	AS <sup>†</sup>	CEC
			(g cm <sup>-3</sup> )	(g kg <sup>-1</sup> )			(mg kg <sup>-1</sup> )			(%)
ANOVA										
Year	2	0.26	0.041	0.021	0.061	0.003	0.011	0.002	0.021	0.004
Treatment	12	0.03	0.031	0.001	0.008	0.002	0.003	0.001	0.018	0.013
Year × Treatment	24	0.32	0.142	0.052	0.302	0.446	0.068	0.651	0.411	0.534
Contrast										
Fertilizer vs. Litter		*	*	**	*	*	**	**	*	**
Fertilizer—linear		*	NS	NS	**	NS	NS	NS	NS	NS
Fertilizer—quadratic		NS	NS	*	NS	NS	NS	NS	NS	NS
Litter—linear		*	NS	**	**	**	**	**	**	**
Litter—quadratic		NS	NS	NS	NS	NS	NS	NS	NS	*

AS = aggregate stability; MBC = microbial biomass C; CEC = cation exchange capacity; BD = bulk density; TN = total N; TC = total C; M3P = Mehlich 3 P; NS = not significant.

\*Significant at probability level of  $P < 0.05$ .

\*\*Significant at probability level of  $P < 0.001$ .



$\text{CaCO}_3$  (added in the diet as source of calcium) that will maintain or increase soil pH when applied to a low-pH soil. Our results are in agreement with Mokolobate and Haynes (2002), who reported in the case of low-pH soils ( $<5.0$ ) such as our soil that the addition of any organic residue would increase soil pH. Inorganic fertilizer N at the highest N rate ( $168 \text{ kg N ha}^{-1}$ ) reduced soil pH by 0.20 units (from 4.96 [original level] to 4.76) after 3 years of annual applications. Our results correspond with the work by Mitchell and Tu (2006), who reported that long-term application of ammonium nitrate to cotton in a Coastal Plain soil resulted in decreasing soil pH by 0.1 to 1.0 units as N rate of ammonium nitrate increased from 67 to  $269 \text{ kg ha}^{-1}$ . Declining pH with inorganic fertilizer was likely due to the acidifying effects of the long-term addition of N fertilizer (Bowman and Halvorson 1998). The acidifying effects of inorganic fertilizer are related to the proton ( $\text{H}^+$ ) production during nitrification of ammoniacal fertilizer (Adams 1984) compared with the liming effects of broiler litter produced by birds fed rations with mineral supplements (Hue 1992).

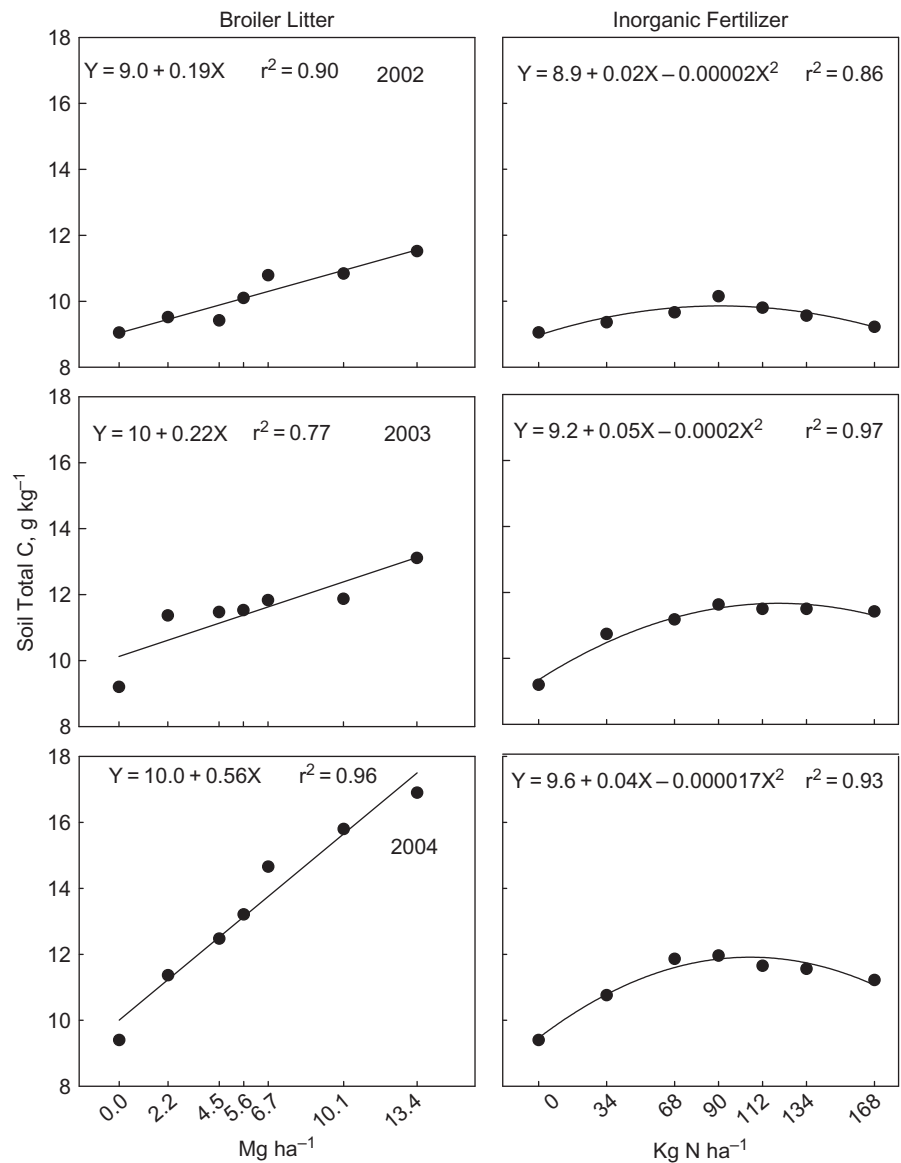
### ***Bulk Density and Aggregate Stability***

Applying commercial fertilizer did not affect bulk density. Soil bulk density was unaffected at the lower rates of broiler litter applications because the amount of organic matter applied to this silt loam soil, with original organic matter content of  $10.59 \text{ g kg}^{-1}$ , was not enough to make a significant difference in soil bulk density. However, at a rate greater than  $6.7 \text{ Mg ha}^{-1}$ , broiler litter application significantly decreased soil bulk density. For example, at the highest broiler litter rate ( $13.4 \text{ Mg ha}^{-1}$ ), soil bulk density decreased by 7% compared to the control (from 1.35 to  $1.26 \text{ g cm}^{-3}$ ; Table 4). The stability of aggregate was not influenced by inorganic fertilizer N applications. However, broiler litter applications linearly increased soil aggregate stability (Table 4). The positive effect of broiler litter application on the stability of aggregate could be related to an increased total C in the soil (Table 4), which would increase biological activities and soil fungal population (Pratt and Tewolde 2008), which produce more organic binding or stabilizing agents for soil macro-aggregate formation followed by soil quality improvement (Angers, Pesant, and Vignaux 1992).

### ***Soil Total C and Microbial Biomass C***

Averaged across broiler litter and inorganic fertilizer N application rate, soil total C increased with increasing year of application (Table 4), indicating the cumulative effects of broiler litter on soil C. Because the Year  $\times$  Treatment interaction was significant (Table 4), soil total C concentration was presented for each year. Fertilizer N applications affected soil C in a quadratic fashion (Figure 1). Although increasing fertilizer N is expected to benefit soil C by increasing plant biomass (Dick 1992), inorganic fertilizer N at rates greater than  $90 \text{ kg N ha}^{-1}$  declined soil total C content and the trend was consistent in each year (Figure 1). For example, in 2004, fertilizer N at the highest rate ( $168 \text{ kg N ha}^{-1}$ ) decreased total soil C by 10% compared to the rate of  $90 \text{ kg N ha}^{-1}$  (from 11.65 to  $10.50 \text{ g kg}^{-1}$ ). Our results are in agreement with work by Khan et al. (2007), who reported that long-term N fertilization depleted soil organic carbon by promoting the decomposition of crop residues and soil organic matter.

Broiler litter application was more effective in increasing soil C than inorganic fertilizer. In each year, total C at the 0 to 15 cm soil depth linearly increased with increasing broiler litter rate and ranged from  $9.4 \text{ g kg}^{-1}$  for the control to  $16.9 \text{ g kg}^{-1}$  for the highest



**Figure 1.** Effects of broiler litter relative to inorganic fertilizer N on soil total C at the 0–15 cm depth.

broiler litter rate (13.4 Mg ha<sup>-1</sup>; Figure 1). The effect of broiler litter on soil C increased with increasing years of application as evidenced by increasing the slope of regression lines ranged from 0.19 in 2002 to 0.56 in 2004 (Figure 1). The greater total soil C with broiler litter than inorganic fertilizer is related to the addition of higher residue or C from broiler litter (Table 3). Similarly, K. Kumar, Sing, and Walia (2000) observed significantly higher C contents in soil receiving manure than plots treated with only inorganic fertilizer. The effects of broiler litter relative to fertilizer N rates on microbial biomass C followed a

similar pattern as soil total C (Table 4). Averaged across years, microbial biomass C was increased with increasing broiler litter application (Table 4). The effects of broiler litter fertilization on microbial biomass C were significantly greater than inorganic fertilizer N (Table 4). Increases in microbial biomass C with increasing broiler litter can be related to the quantity of C substrates (Islam and Weil 2000), which is greater in soils collected from plots receiving broiler litter than those from inorganic fertilizer. This indicates that C is a limiting factor for development of soil microbial activity. Our results are consistent with other reports that have shown that soils receiving animal manures have a larger microbial biomass C than the same soils receiving only chemical fertilizers (Wienhold 2005).

### ***Soil Total N and Residual NO<sub>3</sub>-N***

Total N at the 0 to 15 cm soil depth linearly increased with increasing both broiler litter and fertilizer applications (Table 4). The effect of broiler litter application on soil total N was greater than inorganic fertilizer. For example, averaged across years, total N was 16% greater for broiler litter at the highest rate (13.4 Mg ha<sup>-1</sup>) than inorganic fertilizer at 168 kg N ha<sup>-1</sup> (1.59 vs. 1.33 g kg<sup>-1</sup>, respectively; Table 4).

Residual NO<sub>3</sub>-N concentrations in the soil profile where broiler litter and commercial fertilizer were applied in each year are shown in Table 5. In 2003, the concentration of soil residual NO<sub>3</sub>-N for both N sources was not only greater than those in 2002 and 2004 but its concentration was higher in deeper soil increments (Table 5). This could possibly be related to the weather condition. The year 2003 was an unusual growing season, with a cool and wet spring followed by an extended period of drought and then ending with a wet late summer and fall (Table 6). This condition delayed litter application until the last day of May and cotton was planted on 2 June. The drought condition in July and August when the plants were fruiting might result in less N utilization followed by NO<sub>3</sub>-N accumulation in the soil profile (Table 5). In 2003, greater amounts of rain in late summer and fall (Table 6) increased the potential of leaching NO<sub>3</sub>-N beyond the root zone as evidenced by increasing NO<sub>3</sub>-N concentrations in deeper soil increments (Table 5). Averaged across depth in each year, application of broiler litter and chemical fertilizer increased nitrate N concentration in the soil. Although broiler litter and fertilizer N were applied at equivalent available N, soil NO<sub>3</sub>-N concentration was much greater for commercial fertilizer than broiler litter (Table 5). This might possibly be related to lower available N during the cotton growing season from applied broiler litter as predicted. In 2004, application of broiler litter and commercial fertilizer at rates greater than 6.7 Mg ha<sup>-1</sup> and 90 kg N ha<sup>-1</sup>, respectively, exceeded crop N utilization potential as evidenced by increasing soil nitrate N concentrations (Figure 2). The accuracy of this pattern was confirmed by Tewolde et al. (2010), who reported no yield advantage from broiler litter and commercial fertilizer at rates greater than 6.7 Mg ha<sup>-1</sup> or 90 kg N ha<sup>-1</sup>, respectively, at the same study site.

### ***Soil K, P, and CEC***

Averaged across years, K concentration in the surface soil (0–15 cm) linearly increased with increasing broiler litter applications (Table 4). This indicates the buildup of K in the soil when broiler litter is applied based on N needs of crops. Commercial fertilizer did not significantly increase soil K.

Soil CEC at the 0–15 cm depth linearly increased with increasing broiler litter applications and ranged from 17.5 cmol<sub>+</sub> kg<sup>-1</sup> for the control to 31.3 cmol<sub>+</sub> kg<sup>-1</sup> for broiler litter

at the highest rate of 13.4 Mg ha<sup>-1</sup> (Table 4). Commercial fertilizer N applications did not have a significant effect on soil CEC compared to the control (Table 4). Our results are in agreement with the work of Gao and Chang (1996), who reported that soil CEC increased with increasing manure application.

**Table 5**

Effects of broiler litter application and inorganic fertilizer N on soil NO<sub>3</sub>-N concentrations

		2002	2003	2004
		(mg kg <sup>-1</sup> )		
0–15		7.23	26.58	14.81
15–30		15.55	41.07	15.63
30–60		17.1	46.69	17.04
60–90		12.2	50.4	13.4
LSD <sub>(0.05)</sub>		3.23	3.8	1.21
Broiler litter (Mg ha <sup>-1</sup> )	Fertilizer (kg N ha <sup>-1</sup> )			
0	0	11.84	11.55	9.12
2.2	0	12.54	13.67	9.62
4.5	0	13.94	16.54	11.30
5.6	0	14.76	16.61	11.65
6.7	0	21.55	42.94	14.99
10.1	0	27.30	51.87	16.05
13.4	0	39.23	66.23	20.23
0	34	14.50	15.67	10.71
0	68	17.39	21.05	17.27
0	90	19.39	38.26	21.65
0	112	28.15	61.41	32.20
0	134	36.04	86.50	39.84
0	168	44.03	98.36	48.6
ANOVA				
Depth		0.016	0.003	0.034
Treatment		0.001	0.001	0.001
Depth × Treatment		0.272	0.071	0.094
Contrast				
Fertilizer vs. Litter		**	**	**
Fertilizer—linear		*	**	*
Fertilizer—quadratic		*	**	**
Litter—linear		*	**	*
Litter—quadratic		**	**	*

\*Significant at probability level of  $P < 0.05$ .

\*\*Significant at probability level of  $P < 0.001$ .

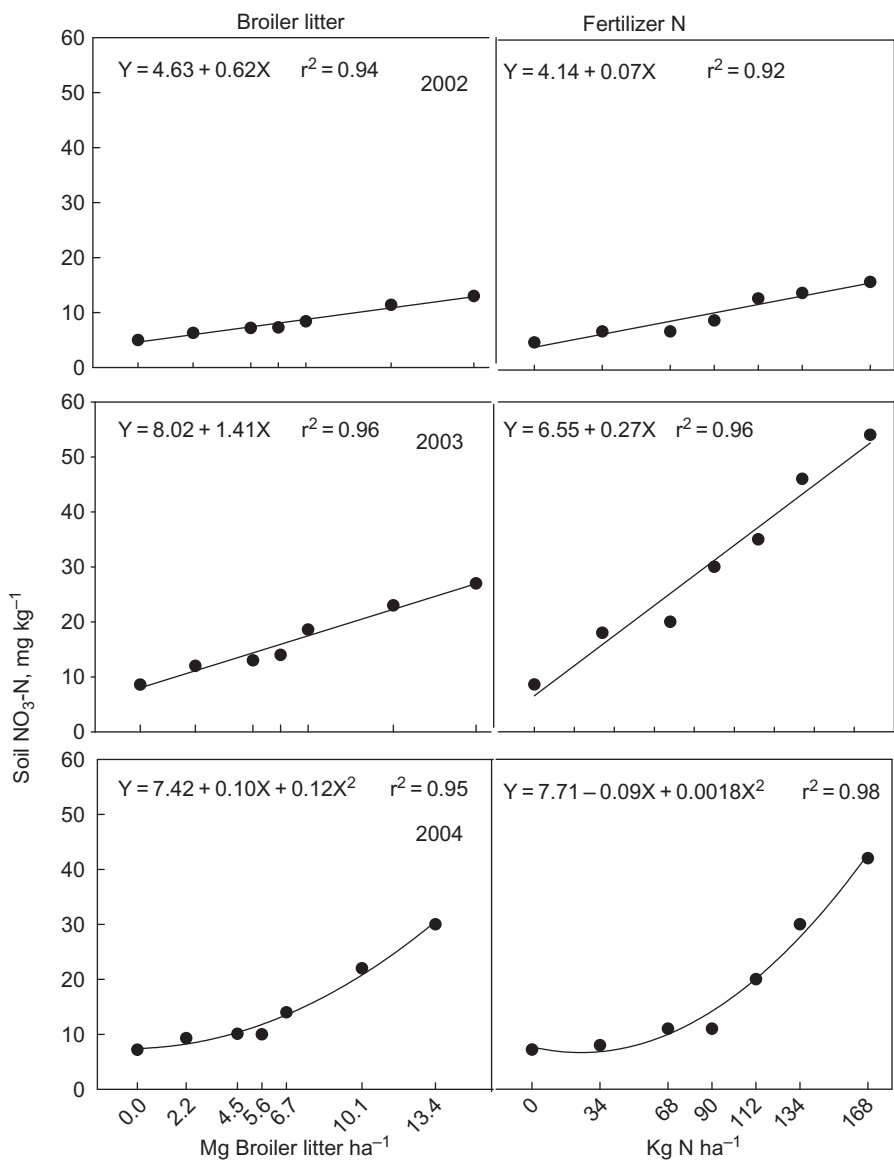
**Table 6**  
Monthly total rainfall during the cotton growing season in 2002 to 2004,  
Holly Springs, Mississippi

Month	Rainfall			
	2002	2003	2004	30-Year average
	(mm)			
March	254	79	103	142
April	32	81	133	138
May	264	289	201	140
June	65	109	154	123
July	87	100	108	109
August	98	40	54	83
September	197	120	62	90
October	244	110	168	110

In each year, the P concentration in the surface soil (0–15 cm) increased with broiler litter application (Figure 3). In each year, regression analysis indicated a linear relationship between broiler litter application and soil P concentration in the surface soil (Figure 3). Increased soil P concentration from broiler litter is related to the loading rate for both sources in each year. For example, after 3 years, a total of 568 kg P ha<sup>-1</sup> was applied at the highest rate of 13.4 Mg ha<sup>-1</sup> broiler litter, but this value was 107 kg P ha<sup>-1</sup> for commercial fertilizer at the recommended rate as determined by the Mississippi Soil Testing Laboratory. Similar to K, broiler litter application based on the N needs of crops resulted in a buildup of soil P. Although approximately 34 kg P ha<sup>-1</sup> was applied to the N-fertilized plot every year, soil P concentration was not significantly affected, indicating that N fertilization either resulted in P removal or inactivated soil P.

## Conclusions

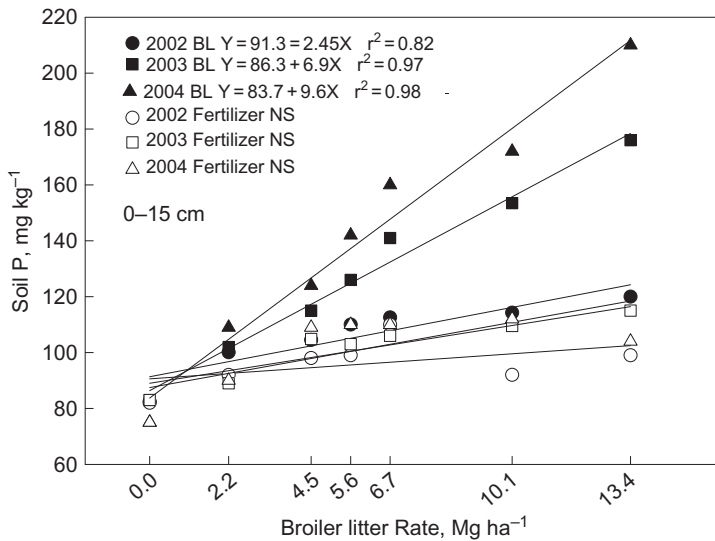
Application of broiler litter for cotton linearly increased soil total C, microbial biomass C, soil total N, and Mehlich 3 P concentration at the 0–15 cm soil depth. However, this pattern was not obtained for commercial fertilizer application at the equivalent N rate. Broiler litter application reduced soil bulk density and increased the stability of soil aggregate compared to the inorganic fertilizer N. Application of broiler litter and inorganic fertilizer N at a rate greater than 6.7 Mg ha<sup>-1</sup> or 90 kg N ha<sup>-1</sup> exceeded plant N utilization potential as evidenced by residual NO<sub>3</sub>-N accumulation in the soil surface. This study indicated that broiler litter is more effective in improving soil property components than conventional fertilizer. As fertilizer N prices rise, if the costs of transporting and applying broiler litter to agricultural lands can be kept low, producers may benefit by reducing the amount of inorganic fertilizer applied to their cotton lands while improving soil quality status.



**Figure 2.** Effects of broiler litter relative to inorganic fertilizer N on soil residual  $\text{NO}_3\text{-N}$  at the 0–15 cm depth.

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**Figure 3.** Effects of broiler litter relative to inorganic fertilizer N on soil Mehlich 3 extractable P at the 0–15 cm depth.

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